Acta Scientific AGRICULTURE (ISSN: 2581-365X)

Volume 7 Issue 2 February 2023

Research Article

Influence of Plant Population Density and Variety on the Growth and Yield Components of Carrot (*Daucus Carota* L.)

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Received: December 20, 2022

Published: January 06, 2023

Abstract

An experiment was conducted to determine the influence of plant population density and varietal differences on the performance of carrot grown in pots. The treatments were plant population density (1, 3 and 5 plants per pot) and varieties (Safety Touchon Mega, Carotte Touchon AM and Carotte Touchon ETS), which were replicated five times in a Completely Randomized Design laid out as split plot experiment. Plant parameters measured were whole plant biomass yield (g), root weight (g), foliage weight (g), root uniformity, root length (cm), and other root metric traits (cm) (proximal, mid, and distal girth). The results revealed that Plant Population Density (PPD) significantly influenced metric growth parameters and all yield components. The intermediate density, PPD 3, significantly produced the highest means for whole plant biomass, root and foliage yield (246.7g, 146.9g and 99.9g) respectively. PPD1 produced the lowest yield values but gave the highest values on root length, proximal and mid girth (14.2cm, 14.7cm and 11.0cm) respectively. PPD 5 recorded the lowest values on root metric growth parameters (10.3, 8.2, 7.2 and 4.8 cm). Among the varieties sown, growth and components of yield did not vary statistically but differed numerically. Carotte Touchon AM recorded the highest values, 198.9g of whole plant biomass yield and 81.1g of foliage weight while Carotte Touchon ETS recorded the highest values on the metric growth parameters except proximal girth. Biplot analyses of the combined effects of population density and genotype suggested three plants per pot of Safety Touchon Mega as the most appropriate for pot planting. Findings from this study revealed variable carrot metric traits and yield as influenced by number of plants per pot and the particular genotype planted.

Keywords: Crop Performance; Carrot Varieties; Planting Density; Potted Vegetables

Introduction

Potting of vegetables is one of the growing horticultural practices in the urban and peri-urban areas of Nigeria due to the limited cultivable land resources available to its dwellers. Carrot, an important vegetable grown for its root, seeds and leaves has a substantial part of its production localized in Northern regions of Nigeria. Carrot (*Daucus carota L.*) is a biennial root crop from the Apiaceae family valued and widely used for its minerals, antioxidants, carotenoids and anthocyanins contents [1-3]. Production of carrot in Southeastern states of Nigeria have not been exploited because of scarce land resources, inherent soil fertility and the belief that it thrives well only in the northern states of Nigeria. This limitation can be resolved by growing carrot and other vegetables that are restricted to the north all year round in containers such as buckets, baskets, earthen or cement pots, used tyres, plastic bottles, tin cans, PVC pipes and mega pots [4]. Pot production of carrot should be encouraged in Nigeria especially in cities, towns and outskirts of rural areas because dwellers of these places use it extensively for salad mixes, baby food, shredded carrot, keto diet, carrot sticks, juice, as a garnish in culinary designs, in creams and facial treatment.

Plant density is an essential agronomic component that impacts crop growth, development, and yield formation by manipulating the microenvironment of the field [5]. Carrot is planted directly, and its population is mostly determined by seed quality among other factors [6-7]. Carrot seeds are tiny, making it difficult to achieve optimal plant population density and spacing without thinning seedlings [8]. According to documentation in Uguru [8], a dense plant population is a major constraint in carrot production, with low root yields as a result of competition for growth conditions. Plant population density has an impact on crop growth and yield, just as it

does on carrot root yield and root size [9]. The seeds are directly sown into the pots or the field, and the population is reduced after emergence to maintain a uniform spacing and density. Plant density is also influenced by the climate and cultivars, which means that the optimal plant density for maximum yield varies depending on genotype and geographic area [5]. The environment and the varieties planted have an impact on the performance of carrots [10].

Carrots come in a variety of shapes and sizes, and there are various types on the market. Danvers carrots, Imperator carrots, Chantenay carrots, and Nantes carrots are the most common varieties [6]. Shape, pigment, size, texture, and maturity all play a role in the variances among these cultivars [2,6]. Against this background, this study was designed to assess the influence of plant population density and variety on the growth and yield performance of carrot grown in pots.

Materials and Methods

The research was conducted at the Teaching and Research Farm of the Department of Crop Science, Faculty of Agriculture, University of Nigeria, Nsukka (latitude $06^0$52'N, longitude $07^0$24'E, altitude 447.26m above sea level). Nsukka is in the derived savannah zone of Nigeria.

Topsoil was collected at a depth of 0-20 cm from the experimental field, pulverised and hard objects were removed. The soil was substituted with 30% rice husk to improve aeration. Ten litres plastic buckets, ninety in number, and obtained from Onitsha, Anambra state, Nigeria, served as the planting containers. The containers would be reused severally until they are weak and unusable, after which they would be gathered and taken to the plastic industry for recycling. Carrot seeds were obtained from seed stores in Jos, Plateau state, Nigeria. Poultry manure and pig slurry (organic substrates) were obtained in an animal farm in Nsukka, Enugu state, Nigeria. The organic substrates were thoroughly mixed with the top of the soil and made even. Three drainage holes were made at the base and side of the planting pots.

Experimental treatments included three planting populations (1, 3, and 5) per pot, and three carrot cultivars (Safety Touchon Mega, Carotte Touchon AM and Carotte Touchon ETS). There were nine treatment combinations replicated five times; experiment lay out was completely randomized design in split plot. After emergence seedlings were thinned to plant populations of 1, 3, and 5 per pot. Weeds were handpicked every two weeks, but insect pests were manually regularly handpicked.

Using a measuring tape, the root length, proximal girth, mid girth, and distal girth were measured in centimetres (cm). The entire plant biomass yield, foliage, and root weight were measured with a measuring scale immediately after harvest, and the unit was grams per pot (g/pot). The data were subjected to an analysis of variance (ANOVA) as described by Obi [11], with significant means separated using the Least Significance Difference (LSD) at a threshold of 5%.

Results

Effects of planting population density and variety on yield components of carrot

Table 1 below shows the main effects of plant population density and genotype on whole plant biomass yield (g/pot), foliage weight (g/pot) and root yield (g/pot). Planting population density had significant effect on all yield components and planting density of three gave the highest values for whole plant biomass yield per pot, root yield per pot and foliage weight (246.7g, 146.9g and 99.9g, respectively). While planting density of one (1) plant per pot gave the least values 155.9 g and 99.1 g, on whole plant biomass yield per pot and root yield per pot. Table 1 revealed that genotype had no significant ($p > 0.05$) effect on the yield components of carrot studied. However, Carotte Touchon AM recorded the highest whole plant biomass yield per pot. Carotte Touchon ETS recorded the highest root yield per pot (g/pot) while Safety Touchon Mega gave the least values on whole plant biomass yield per pot and root yield per pot.

Effects	Yield components			
	NHR	WPBY(g)	RW(g)	FW(g)
Plant Population Density (per pot)				
PPD 1	1.0	155.9	99.1	56.7
PPD 3	3.0	246.7	146.9	99.9
PPD 5	5.0	179.4	103.6	75.8
$LSD_{(0.05)}$	NS	42.4	36.4	13.4
Genotypes				
Safety Touchon Mega	3.0	185.6	110.9	74.7
Carotte Touchon AM	3.0	198.9	117.8	81.1
Carotte Touchon ETS	3.0	197.5	120.9	76.5
$LSD_{(0.05)}$	NS	NS	NS	NS

Table 1: Main effects of planting population density and genotypes on yield components of carrot grown in pots.

NHR: Number of Harvested Roots WPBYH: Whole Plant Biomass Yield per Pot, FWP: Foliage Weight per Pot, RYP: Root Weight per Pot. PPD 1: Plant Population Density 1, PPD 3: Plant Population Density 3, PPD 5: Plant Population Density 5

Response of yield components of carrot to the combined effects of plant population density and variety

Figure 1 revealed the joint effects of plant population density and genotype on the yield parameters evaluated. Plant population density of three plants per pot gave the best root weight and whole plant biomass yield when Safety Touchon Mega (D3-Stm) was planted. This was closely followed by Carotte Touchon ETS (D3-Cte). Planting one plant or five per pot of these genotypes were sub-optimal in performance. Variable traits-by-genotype as influenced by plant population density per pot was evident (Figure 1). The biplot explained 100% of the total variations due to genotype and plant population.

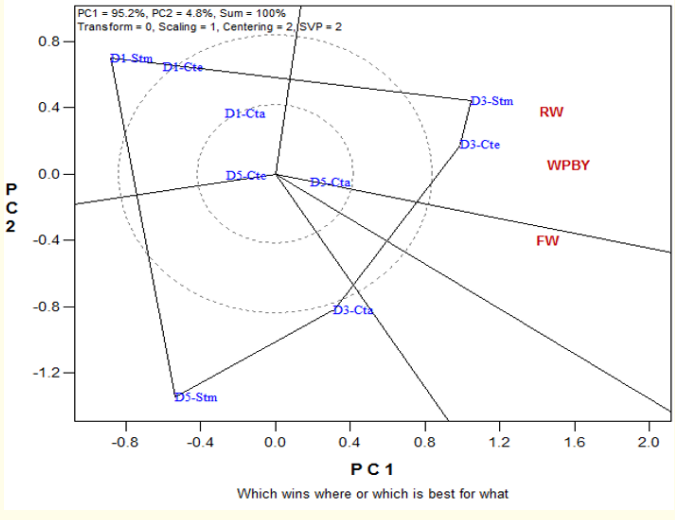

Figure 1: Traits-by-genotype biplot analysis of components of yield of carrot as influenced by plant population density. Stm: Safety Touhon Mega; Cta: Carotte Touchon AM; Cte: Carotte Touchon ETS; D1: Population Density of 1 Plant; D3: Population Density of 3 Plants; D5: Popuation Density of 5 Plants; WPBY: Whole Plant Biomass Yield; RW: Root Weight; FW: Foliage Weight

Effects of planting population density and variety on metric (cm) growth components of carrot

Table 2 shows the effect of plant populations and genotype on the root length, proximal girth and middle girth of carrot roots grown in pots. Plant population had significant ($p < 0.05$) effect on the growth parameters. Pots in which carrot seedlings were thinned down to one (1) gave the highest values 14.2cm, 14.7cm, and 11.0cm, on root length, proximal girth and mid girth respectively. However, pot in which carrot seedlings were thinned down to one (1) and three (3) plants per pot recorded the same value on distal girth (5.3cm). Five (5) carrot plants per pot recorded the least values on length, proximal girth, mid girth and distal girth. Also from the result, genotype had no significant ($p > 0.05$) effect on these growth parameters of carrot roots grown in pots. However, Carotte Touchon ETS recorded the longest root (12.2 cm), also gave the highest values on mid girth and distal girth (9.5 cm and 5.4 cm respectively). Carotte Touchon AM gave the highest value on the proximal girth (11.8 cm) while Safety Touchon Mega has the lowest values in all of the roots' metric parameters.

Effects	Root Length (cm)	Proximal girth (cm)	Mid girth (cm)	Distal Girth (cm)
Plant Population Density				
PPD 1	14.2	14.7	11.0	5.3
PPD 3	11.6	11.1	9. 9	5.3
PPD 5	10.3	8.2	7.2	4.8
$LSD_{(.05)}$	1.8	1.3	1.3	NS
Genotypes				
Safety Touchon Mega	12.1	10.9	9.2	4.9
Carotte Touchon AM	11.8	11.8	9.4	5.2
Carotte Touchon ETS	12.2	11.3	9.5	5.4
$LSD_{(0.05)}$	NS	NS	NS	NS

Table 2: Main Effects of Plant Population and Genotypes on Metric (cm) Growth Parameters of Carrot Roots in Pots.

PPD 1: Plant Population Density 1, PPD 3: Plant Population Density 3, PPD 5: Plant Population Density 5.

Effect of the interaction of plant population and genotypes on carrot metric growth parameters

The interaction of plant population and genotype effect on metric traits of carrot roots grown in pots is shown in figure 2. Root metric traits (root length, root proximal and middle girth) reveal shape and visual appeals of carrot roots. The combined effects of genotype and population density influenced these traits showing vivid distinction (Figure 2). One plant per pot of Carotte Touchon ETS (D1-Cte) and Safety Touchon Mega (D1-Stm) produced the longest roots. However, one plant per pot of Carotte Touchon AM (D1-Cta) had bigger root girth. D3-Cta and D3-Stm had average metric traits. The biplot explained 98.5% of the total variation.

Discussion

Plant population affected all yield components significantly. In general, there were substantial differences in root length, root girth, and root weight among the treatments. The carrot plants that were thinned down to one (1) plant per pot produced longer roots than the other planting densities. Bahlgerdi., *et al.* [12] dis-

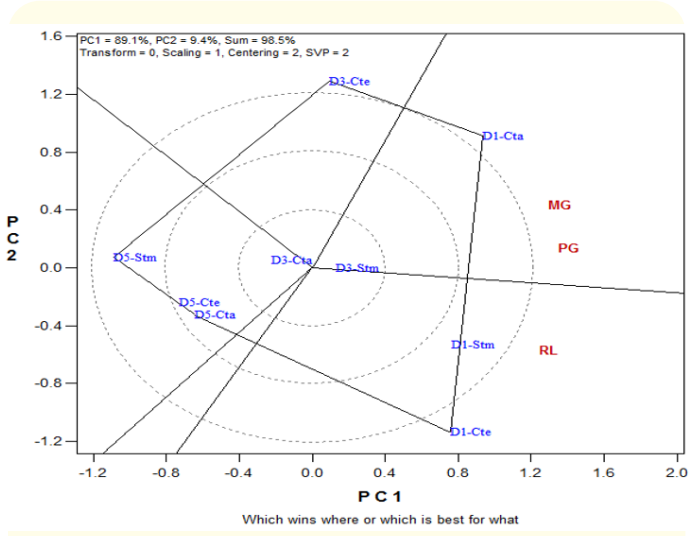

Figure 2: Biplot analysis of combined effects of genotype and plant population density on metric traits of carrot.
Stm: Safety Touhon Mega; Cta: Carotte Touchon AM; Cte: Carotte Touchon ETS; D1: population density of 1 plant; D3: population density of 3 plants; D5: popuation density of 5 plants; RL: Root lenght; PG: Proximal girth; MG: Middle girth

covered that medicinal pumpkin had the longest plant length at the lowest plant density. Reduced planting density of carrot seedlings to one plant per pot also resulted in heavier and fibrous carrot roots, which would serve for cooking. This could be due to less competition for essential soil minerals and sunlight, which allows photosynthates to accumulate in the roots, as well as greater apical growth and reduced side branching [13]. Kumar [14] observed similar results in the study of effect of planting density on carrot. Plant height and length are often reduced when plant density is increased in other crops due to competition for space, nutrients, and sunlight. Closer spacing of plant population density of three (3) plants per pot, for example, resulted in a higher carrot root per pot [15,16]. In contrast, Kabir., *et al.* [17] found that plants planted at the widest spacing produced the highest yield. This is because the desired root usage has its own specific root size range [18]; the discrepancy could be due to the goal of the planned carrot use.

Plant population density of five (5) plants per pot had the lowest values for all growth and yield components, implying that the higher the planting density, the lower the root yield components and the lower the marketable value. This is in line with Rahman and Hossain [5] findings that increasing plant density per unit space increases competition for key growth elements among individual plants, causing them to grow slower than expected. For this reason, smaller but juicy roots were generated per unit area of PPD 5 and succulent large root yields were significantly ($p < 0.05$) greater in the carrot plants thinned down to three (3) plants per pot. The largest individual roots were produced from the lowest population, PPD 1. Increased Plant Population Density (PPD) reduces growth and yield per plant within specific limits, but the opposite is true for yield per unit area [19]. When the population density was increased to three plants per pot, root yield output rose considerably. In contrast, as the population expanded to a planting density of five plants per plant, the root size and weight declined considerably. This was not in agreement with the findings of Dawuda., *et al.* [15] and Shiberu and Tamiru [16], who found that increasing plant density with closer spacing enhanced carrot root output.

Variations in the potted carrots' development and yield components were influenced by the cultivars as well as an external element, plant population. Although there were numerical differences, the carrot types had no meaningful impact on the crop's growth and yield components. The non-significant differences among the cultivars evaluated with respect to plant population density suggested that all the varieties had similar genetic yielding potential.

Conclusion

The best root output was obtained by thinning carrot seedlings to a plant population density of three (3) plants per pot, resulting in succulent roots for raw consumption as carrot sticks, juice, and salad. While thinning down to one (1) plant population density, the highest values on metric growth parameters were recorded, resulting in carrot roots that were exceptionally large and fibrous, resulting in outsized roots useful only for cooking and as garnish. Five (5) plants per pot of the 10-liter-pot size employed produced juicy but slender roots, resulting in reduced marketable value. We recommend thinning down to a plant population density of three (3) plants per pot within the limit of the pot size (10 litres) utilised in the study.

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